



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.034>

STUDIES ON POTASSIUM FRACTION IN SODIC SOIL AS INFLUENCED BY POTASSIUM APPLICATION

Varsha Shankarappa*, Ashoka K. R., Savitha H. R. and Hanamantappa Meti

College of Agriculture, V. C. Farm, Mandya, Karnataka, India

*Corresponding author E-mail: varshagowda21121999@gmail.com

(Date of Receiving-22-11-2025; Date of Revision-28-12-2025; Date of Acceptance-10-02-2026)

ABSTRACT

The field experiment was conducted to examine the role of potassium fertilizer management in mitigating the adverse effects of soil sodicity on rice during the *Kharif* – 2023. The salt tolerant IR 30864 rice cultivar was used as test crop and the experiment was laid out in a randomized complete block design with three replications. The Treatments involved split applications of potassium at three distinct levels, administered both individually and alongside foliar potassium sprays. Collected soil samples after harvest were assessed for various forms of potassium, while plant samples were analysed for nutrient uptake. The results demonstrated that three split applications of potassium significantly enhanced nutrient uptake compared to two splits. Notably, the treatment with three splits at a rate of 75 kg ha⁻¹ (T₁₂) resulted in the highest total potassium uptake, recorded at 120.60 kg ha⁻¹. Furthermore, the different potassium fractions at harvest specifically water-soluble K (10.49 mg kg⁻¹), available K (119.95 mg kg⁻¹) and exchangeable K (107.08 mg kg⁻¹) were higher in T₁₂. However, variations in non-exchangeable, lattice and total potassium among the treatments were not significant. The distribution of potassium fractions in the soil followed the order: Total K > lattice K > non-exchangeable K > available K > exchangeable K > water-soluble K. All potassium fractions were maximized in the treatment utilizing three split applications, highlighting the effectiveness of this approach in sodic soils.

Key words: Potassium Fraction, Sodicity, Salt Tolerant

Introduction

The Cauvery command area in Karnataka, with its expansive 2.5 million hectares of fertile land, serves as a vibrant agricultural epicenter in southern India. However, as we progress into 2024, this region grapples with a pressing challenge: the increasing incidence of sodic soil, which threatens food security.

Currently, around 30% of the cultivated land in the Cauvery command area suffers from varying degrees of salinity and sodicity, while nearly 7% of global agricultural land is compromised by salt. Sodic soils pose significant barriers to rice cultivation by accumulating detrimental levels of soluble salts, particularly sodium (Na⁺) and bicarbonates (HCO₃⁻). This toxic accumulation disrupts plant growth and yield, inducing ionic, osmotic and oxidative stresses that compromise the overall health of rice plants. Elevated sodium levels interfere with

potassium (K⁺) uptake, a critical nutrient essential for numerous physiological and biochemical processes in plants.

Potassium is required by plants in substantial quantities, often on par with or exceeding the demand for nitrogen (N). Its role is vital, influencing photosynthesis, enzyme activation, and overall water regulation. (Pettigrew, 2008; Zorb *et al.*, 2014). Unfortunately, potassium is inherently less mobile in soils due to its strong binding to clay particles. The historical under application of potassium fertilizers has led to a dependency on native soil reserves, resulting in depletion through continuous cropping practices and leaching during flooding- a necessity for rice cultivation (Mehdi *et al.*, 2001)

In soils, potassium exists in four forms: water-soluble K, exchangeable K, non-exchangeable K and fixed K. The dynamic equilibrium among these forms necessitates

careful management to prevent depletion and ensure a continuous supply for rice crops. Innovative approaches, such as split application and foliar spraying are emerging as effective strategies to address potassium deficiencies in sodic soils. Split application allows for the distribution of potassium across multiple doses throughout the cropping season, enhancing nutrient uptake and mitigating leaching losses. By adopting these methods, we can significantly improve potassium availability and uptake, thereby boosting rice performance in salt-affected environments. (Garg and Gupta, 1997). In this context, the present investigation was undertaken to evaluate the efficacy of these potassium management strategies in alleviating the detrimental impacts of salinity on rice cultivation, aiming to contribute to the sustainability and resilience of rice production in affected regions.

Material and Methods

In an effort to enhance rice cultivation on sodic soil, a field experiment was conducted during the *Kharif* season of 2023 at the B Block of the Zonal Agricultural Research Station,

V.C. Farm, Mandya. The research focused on evaluating the effectiveness of split applications of potassium fertilizer. Following the recommended nutrient application rates for sodic soils, nitrogen and phosphorus were supplied at 125 and 62.5 kg ha⁻¹, respectively, while potassium was applied at three different levels: 50, 62.5, and 75 kg ha⁻¹, which was applied either in two splits: 50% as a basal dose and 50% at 50 DAT or by three splits: 50% as a basal dose, 25% at 30 DAT and 25% at 50 DAT and additionally, two splits along with a foliar spray of potassium nitrate or potassium sulfate. Sources of N, P and K were urea, SSP and MOP, respectively. Zinc was also applied to all treatments in the form of ZnSO₄·7H₂O at a rate of 40 kg ha⁻¹ during transplanting. The experiment utilized a randomized complete block design (RCBD) and comprised twelve distinct treatments, each replicated three times, to systematically assess the various strategies for potassium fertilization.

Details of the experiment treatments

T ₁ : K ₂ O 50 kg ha ⁻¹ applied in 2split
T ₂ : T ₁ + FS of 2%KNO ₃ at 30 DAT
T ₃ : T ₁ + FS of 2% K ₂ SO ₄ at 30 DAT
T ₄ : K ₂ O 50 kg ha ⁻¹ applied in 3split
T ₅ : K ₂ O 62.5 kg ha ⁻¹ applied in 2split
T ₆ : T ₅ + FS of 2%KNO ₃ at 30 DAT
T ₇ : T ₅ + FS of 2% K ₂ SO ₄ at 30 DAT
T ₈ : K ₂ O 62.5 kg ha ⁻¹ applied in 3split

T₉: K₂O 75 kg ha⁻¹ applied in 2 split

T₁₀: T₉+ FS of 2%KNO₃ at 30 DAT

T₁₁: T₉+ FS of 2% K₂SO₄ at 30 DAT

T₁₂: K₂O 75 kg ha⁻¹ applied in 3 split

Soil samples were collected and air-dried before analysis. Water-soluble K was determined using a 1:5 soil-water suspension, equilibrated for one hour, with potassium measured *via* flame photometry (Dhawan *et al.*, 1968). Exchangeable K was assessed by treating 5 g of soil with 25 mL of neutral normal ammonium acetate. The mixture was shaken for 5 minutes and filtered, with the potassium in the filtrate measured using flame photometry. Exchangeable K was calculated by subtracting water-soluble K from the potassium extracted with 1N NH₄OAc, *i.e.*, available potassium (Jackson, 1973). Non-exchangeable K was determined by boiling 5 g of soil with 1N HNO₃ in a 2.5:25 soil-to-acid ratio for 10 minutes. The mixture was then filtered, and the residue washed with 0.1 N HNO₃. The potassium content in the extract was measured, and the amount obtained from the NH₄OAc extract was subtracted to calculate non-exchangeable potassium. Total potassium content was analysed by digesting 0.1 g of the soil sample in a closed polypropylene bottle with 2 mL of aqua regia (HNO₃, 1:10) and 10 mL of HF acid. The sample was shaken for 2 to 8 hours, after which the residue was dissolved in 50 mL of 6 N HCl. The final volume was adjusted to 100 mL with distilled water and total potassium was measured using flame photometry (Lim and Jackson, 1982). Lattice potassium was calculated as the difference between total potassium and the sum of water-soluble, exchangeable and non-exchangeable K fractions.

The uptake of nutrients at harvest was worked out using the formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{grain or straw yield (kg ha}^{-1}\text{)}}{100}$$

Total uptake = uptake by grain + uptake by straw

Results and Discussion

Macronutrient uptake in rice under varying potassium treatments

The uptake of nitrogen (N), phosphorus (P) and potassium (K) in rice was significantly influenced by varying rates of potassium application (Table 1). Both grain and straw nutrient uptake showed marked differences due to the main effects of split and foliar applications, as well as interactions between potassium sources and application methods. Notably, treatments involving three split applications resulted in significantly higher nutrient uptake compared to other methods.

Table 1: Effect of potassium management on grain, straw and total uptake of N, P and K by rice in sodic soil.

Treatments	N uptake (kg ha ⁻¹)			P uptake (kg ha ⁻¹)			K uptake(kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T ₁ : K ₂ O 50 kg ha ⁻¹ applied in 2 split	43.78	34.01	77.79	9.98	7.21	17.20	19.82	55.79	75.61
T ₂ : T ₁ + FS of 2%KNO ₃ at 30 DAT	51.65	40.33	91.98	12.19	9.97	22.16	23.33	65.97	89.31
T ₃ : T ₁ + FS of 2% K ₂ SO ₄ at 30 DAT	46.72	37.09	83.82	10.74	8.51	19.25	21.53	60.73	82.27
T ₄ : K ₂ O 50 kg ha ⁻¹ applied in 3split	52.02	40.18	92.20	12.14	9.77	21.91	23.76	67.46	91.22
T ₅ : K ₂ O 62.5 kg ha ⁻¹ applied in 2split	53.83	43.82	97.66	13.65	11.84	25.48	27.24	73.95	101.18
T ₆ : T ₅ + FS of 2%KNO ₃ at 30 DAT	63.93	51.98	115.91	17.85	14.41	32.26	32.04	86.00	118.04
T ₇ : T ₅ + FS of 2% K ₂ SO ₄ at 30 DAT	57.26	46.66	103.92	14.84	12.03	26.88	27.92	78.51	106.44
T ₈ : K ₂ O 62.5 kg ha ⁻¹ applied in 3split	64.53	52.58	117.11	18.01	14.65	32.66	32.65	87.65	120.30
T ₉ : K ₂ O 75 kg ha ⁻¹ applied in 2 split	52.78	43.77	96.54	14.31	10.89	25.20	27.02	72.71	99.73
T ₁₀ : T ₉ + FS of 2%KNO ₃ at 30 DAT	64.47	52.45	116.91	17.92	14.51	32.44	32.59	87.39	119.98
T ₁₁ : T ₉ + FS of 2% K ₂ SO ₄ at 30 DAT	58.37	47.35	105.72	15.50	12.76	28.26	29.39	79.52	108.91
T ₁₂ : K ₂ O 75 kg ha ⁻¹ applied in 3 split	64.87	52.73	117.60	18.15	14.71	32.86	32.71	87.88	120.60
SEm±	2.11	1.22	2.31	0.69	0.42	0.69	1.07	2.37	2.51
CD (P≤0.05)	6.19	3.58	6.78	2.01	1.23	2.01	3.13	6.95	7.73

Nitrogen uptake demonstrated significant variation among treatments, primarily due to the split application of K fertilizers under sodic conditions. Treatment T₁₂ recorded the highest N uptake in grain and straw (64.87 and 52.73 kg ha⁻¹, respectively), while treatment T₁ displayed the lowest values (43.78 and 34.01 kg ha⁻¹, respectively). Total nitrogen uptake followed a similar trend, with T₁₂ achieving 117.60 kg ha⁻¹ compared to 77.79 kg ha⁻¹ in T₁.

Phosphorus uptake also exhibited significant differences, with treatment T₁₂ showing elevated levels for both grain and straw (18.15 and 14.71 kg ha⁻¹, respectively) and a total uptake of 32.86 kg ha⁻¹. Conversely, treatment T₁ recorded lower phosphorus uptake (9.98 and 7.21 kg ha⁻¹, respectively), resulting in a total of 17.20 kg ha⁻¹.

Among the split application treatments, T₁₂, employing three splits, achieved the highest potassium uptake in grain and straw (32.71 and 87.88 kg ha⁻¹, respectively), whereas treatment T₁ has lower uptake values (19.82 and 55.79 kg ha⁻¹, respectively). Overall nutrient uptake reflected this pattern, with the highest total in treatment T₁₂ (120.60 kg ha⁻¹) and the lower in treatment T₁ (75.61 kg ha⁻¹).

Potassium application significantly improves the uptake of nitrogen and phosphorus, due to synergetic effect on uptake of nitrogen and other nutrients resulting in enhanced plant growth and increased dry matter production (Patil *et al.*, 2017 and Chaudhari *et al.*, 2018). The application of potassium in split doses ensures a steady supply throughout the growing season, supporting optimal nutrient absorption. The synergistic relationship between

Table 2: Effect of potassium management on water soluble K and available K of soil at different growth stages under sodic soil.

Treatments	Water soluble K (mg kg ⁻¹)			Available K (mg kg ⁻¹)		
	30 DAS	60 DAS	AtHarvest	30 DAS	60 DAS	AtHarvest
T ₁ : K ₂ O 50 kg ha ⁻¹ applied in 2 split	7.68	7.00	6.15	105.45	89.22	74.22
T ₂ : T ₁ + FS of 2%KNO ₃ at 30 DAT	7.82	7.20	6.39	112.17	92.32	78.07
T ₃ : T ₁ + FS of 2% K ₂ SO ₄ at 30 DAT	8.19	7.56	6.85	119.32	99.37	80.97
T ₄ : K ₂ O 50 kg ha ⁻¹ applied in 3split	9.14	8.34	7.53	124.72	110.92	88.27
T ₅ : K ₂ O 62.5 kg ha ⁻¹ applied in 2split	9.06	8.30	7.41	124.32	110.87	86.92
T ₆ : T ₅ + FS of 2%KNO ₃ at 30 DAT	9.20	8.56	8.03	129.87	116.47	93.47
T ₇ : T ₅ + FS of 2% K ₂ SO ₄ at 30 DAT	9.65	9.29	8.33	132.57	121.47	95.42
T ₈ : K ₂ O 62.5 kg ha ⁻¹ applied in 3split	10.99	10.62	9.81	138.42	128.52	109.70
T ₉ : K ₂ O 75 kg ha ⁻¹ applied in 2 split	11.13	10.14	9.67	138.18	131.62	108.82
T ₁₀ : T ₉ + FS of 2%KNO ₃ at 30 DAT	11.58	10.94	10.21	145.32	137.02	110.62
T ₁₁ : T ₉ + FS of 2% K ₂ SO ₄ at 30 DAT	11.86	11.22	10.41	147.32	135.37	114.22
T ₁₂ : K ₂ O 75 kg ha ⁻¹ applied in 3 split	12.05	11.30	10.49	153.07	145.17	119.95
SEm±	0.26	0.28	0.27	3.56	3.59	3.00
CD (P≤0.05)	0.77	0.82	0.79	10.43	10.53	8.81

Table 3: Effect of potassium management on exchangeable K and non-exchangeable K of soil at different growth stages under sodic soil.

Treatments	Exchangeable K (mg kg ⁻¹)			Non-exchangeable K (mg kg ⁻¹)		
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest
T ₁ : K ₂ O 50 kg ha ⁻¹ applied in 2 split	97.59	82.14	68.02	328.02	325.35	327.35
T ₂ : T ₁ + FS of 2% KNO ₃ at 30 DAT	104.25	85.04	71.63	329.75	327.08	329.08
T ₃ : T ₁ + FS of 2% K ₂ SO ₄ at 30 DAT	111.10	91.73	74.07	330.21	327.54	329.54
T ₄ : K ₂ O 50 kg ha ⁻¹ applied in 3split	115.58	102.50	80.69	330.83	328.16	330.16
T ₅ : K ₂ O 62.5 kg ha ⁻¹ applied in 2split	115.36	101.49	79.46	331.05	328.38	330.38
T ₆ : T ₅ + FS of 2% KNO ₃ at 30 DAT	120.37	107.49	85.39	332.80	330.13	332.13
T ₇ : T ₅ + FS of 2% K ₂ SO ₄ at 30 DAT	122.79	112.43	87.04	333.09	330.42	332.42
T ₈ : K ₂ O 62.5 kg ha ⁻¹ applied in 3split	129.73	121.15	94.51	335.35	332.68	334.68
T ₉ : K ₂ O 75 kg ha ⁻¹ applied in 2 split	129.62	120.73	93.43	334.27	331.60	333.60
T ₁₀ : T ₉ + FS of 2% KNO ₃ at 30 DAT	133.64	126.00	100.36	335.72	333.05	335.05
T ₁₁ : T ₉ + FS of 2% K ₂ SO ₄ at 30 DAT	135.36	124.07	103.76	336.49	333.82	336.15
T ₁₂ : K ₂ O 75 kg ha ⁻¹ applied in 3 split	140.99	133.79	107.08	336.60	333.93	335.93
SEm±	3.56	3.46	2.78	9.64	9.66	9.70
CD (P≤0.05)	10.43	10.15	8.16	NS	NS	NS

potassium and nitrogen boosts nitrogen assimilation by maintaining essential enzymes like nitrate and nitrite reductases, which are critical for efficient nitrogen uptake (Safaa *et al.*, 2013). Inorganic K fertilizers have been shown to enhance rice plant growth by improving photosynthesis and the transport of phosphorus, leading to higher dry matter yields. Additionally, potassium modulates interactions with sodium in saline soils, improving nutrient acquisition and plant performance under stress. It also helps manage soil pH and structure, reduces nutrient leaching and ensures consistent nutrient availability, which further supports plant health. Potassium improves stomatal conductance, enhancing CO₂ absorption and nutrient distribution, thus stimulating root growth and overall nutrient uptake (Hou *et al.*, 2019).

In this study, applying 75 kg ha⁻¹ of K resulted in the highest K⁺ uptake, with similar grain yields observed at 62.5 kg ha⁻¹, suggesting that higher application rates may lead to luxury consumption (Ravichandran and Sriramachandrasekharan, 2011). These findings are consistent with previous studies, which indicate that potassium enhances nutrient acquisition in saline soils and mitigates the negative effects of salinity or sodicity stress on nutrient uptake. Overall, potassium plays a crucial role in improving the efficiency of nutrient uptake, particularly in improving nitrogen and phosphorus acquisition in plants.

Potassium fractions

Potassium is known as quality element and required by plants for healthy growth, but Indian agriculture has traditionally relied on the native soil resource of potassium. (Annapurna *et al.*, 2017). Understanding how potassium transforms and moves through soil is essential as its availability is determined by the distribution of its different

forms. The present study revealed that the various fractions of potassium follow in the order of Total K > Lattice K > Non-exchangeable K > Exchangeable K > Available K > Water soluble K. (Gnanasundari *et al.*, 2020).

Effect of potassium application on water soluble and available potassium

The potassium content in sodic soil fluctuated notably throughout the rice plant's growth stages, influenced by the split application of potassium at various levels, as outlined in Table 2. Water-soluble and available potassium concentrations ranged from 7.68 to 12.05 mg kg⁻¹ and 105.45 to 153.07 mg kg⁻¹ at 30 DAT, 7.00 to 11.30 mg kg⁻¹ and 89.22 to 145.17 mg kg⁻¹ at 60 DAT and 6.15 to 10.49 mg kg⁻¹ and 74.22 to 119.95 mg kg⁻¹ at harvest, respectively. The highest concentrations of both water-soluble and available potassium were recorded in treatment T₁₂, where three split doses of 75 kg ha⁻¹ K₂O were applied during each growth stage. Thippeswamy *et al.*, (1995) observed that the available potassium fraction increased with higher potassium doses and split

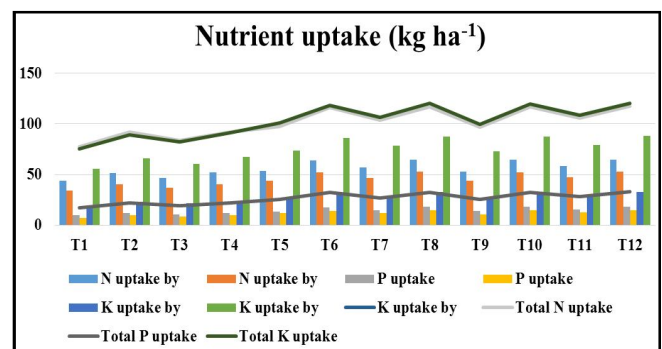
**Fig. 1:** Influence of potassium management on nutrient

Table 4: Effect of potassium management on lattice K and total K of soil at different growth stages under sodic soil.

Treatments	Lattice K (mg kg ⁻¹)			Total K (mg kg ⁻¹)		
	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest
T ₁ : K ₂ O 50 kg ha ⁻¹ applied in 2 split	8183.38	8137.18	8175.15	8616.00	8551.00	8576.00
T ₂ : T ₁ + FS of 2% KNO ₃ at 30 DAT	8214.85	8187.35	8219.57	8656.00	8606.00	8626.00
T ₃ : T ₁ + FS of 2% K ₂ SO ₄ at 30 DAT	8237.18	8219.84	8251.21	8686.00	8646.00	8661.00
T ₄ : K ₂ O 50 kg ha ⁻¹ applied in 3 split	8271.12	8252.67	8283.29	8726.00	8691.00	8701.00
T ₅ : K ₂ O 62.5 kg ha ⁻¹ applied in 2 split	8261.20	8238.50	8279.42	8716.00	8676.00	8696.00
T ₆ : T ₅ + FS of 2% KNO ₃ at 30 DAT	8284.30	8260.49	8301.12	8746.00	8706.00	8726.00
T ₇ : T ₅ + FS of 2% K ₂ SO ₄ at 30 DAT	8311.15	8289.53	8328.88	8776.00	8741.00	8756.00
T ₈ : K ₂ O 62.5 kg ha ⁻¹ applied in 3 split	8330.61	8322.22	8357.67	8806.00	8786.00	8796.00
T ₉ : K ₂ O 75 kg ha ⁻¹ applied in 2 split	8316.65	8304.20	8339.97	8791.00	8766.00	8776.00
T ₁₀ : T ₉ + FS of 2% KNO ₃ at 30 DAT	8335.73	8321.68	8356.05	8816.00	8791.00	8801.00
T ₁₁ : T ₉ + FS of 2% K ₂ SO ₄ at 30 DAT	8362.96	8695.86	8391.01	8846.00	8831.00	8841.00
T ₁₂ : K ₂ O 75 kg ha ⁻¹ applied in 3 split	8377.04	8362.65	8394.17	8866.00	8841.00	8847.67
SEm±	239.27	240.07	242.07	255.07	253.94	254.71
CD (P≤0.05)	NS	NS	NS	NS	NS	NS

applications further boosted its availability. As the rice plant progressed through its growth phases, vegetative and reproductive, the plant's potassium demand grew causing a reduction in the available potassium levels in the soil (Liu and Yao, 2003).

Effect of potassium application on exchangeable and non-exchangeable potassium

The fractions of potassium in the soil during rice growth showed a clear distinction between exchangeable and non-exchangeable fractions. While exchangeable potassium varied significantly throughout the different growth stages of the rice plant, non-exchangeable potassium remained relatively stable despite changes in potassic fertilizer rates and application methods. The exchangeable and non-exchangeable potassium levels ranged from 97.59 to 140.99 mg kg⁻¹ and 328.02 to 336.60 mg kg⁻¹ at 30 DAT, 82.14 to 133.79 mg kg⁻¹ and 325.25 to 333.93 mg kg⁻¹ at 60 DAT, and 68.02 to 107.08 mg kg⁻¹ and 327.35 to 335.93 mg kg⁻¹ at harvest, respectively (Table 3). The non-exchangeable potassium levels in sodic soil were observed to be lower after 30 DAT.

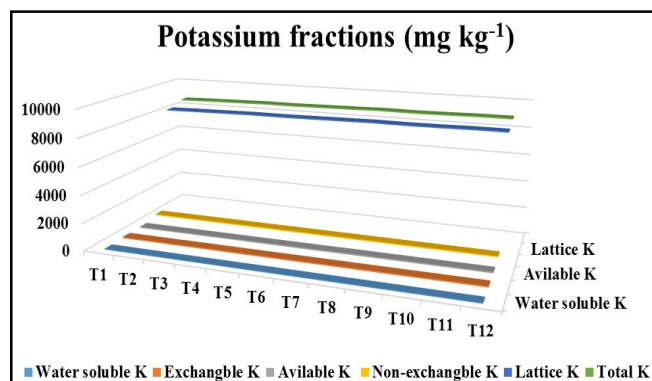


Fig. 2: Impact of potassium management on soil potassium fractions at harvest in sodic soil.

This decline can be attributed to the slow release of potassium from non-exchangeable sites to exchangeable sites, in response to the crop's increasing potassium demand, which maintains a dynamic equilibrium among the different potassium fractions (Das *et al.*, 1993). The lack of significant response of non-exchangeable potassium to different fertilization treatments suggests that this fraction is not as readily influenced by potassium fertilizer applications, instead responding more to natural soil processes and plant uptake patterns over time. Nand *et al.*, 2019.

Effect of potassium application on lattice and total potassium

The impact of varying potassic fertilizer application rates on lattice and total potassium content during different rice growth stages was minimal, as shown in Table 4. Lattice and total potassium concentrations ranged from 8183.38 to 8377.04 mg kg⁻¹ and 8616.03 to 8866.18 mg kg⁻¹ at 30 days after transplanting (DAT), 8137.18 to 8362.65 mg kg⁻¹ and 8551.27 to 8841.24 mg kg⁻¹ at 60 DAT, and 8175.15 to 8394.17 mg kg⁻¹ and 8576.07 to 8847.74 mg kg⁻¹ at harvest, respectively. Despite differences in fertilizer application methods and timing, lattice and total potassium levels remained relatively unchanged throughout the growth cycle. This stability is likely due to the soil's inherent capacity to retain potassium within its mineral structure, which limits the impact of external fertilizer rates on these potassium fractions. The slow release and reduced mobility of potassium from these fixed forms contribute to the observed minimal fluctuations, supporting the findings of Sharma and Verma (2000), who highlighted that potassium in sodic soils tends to remain bound and is less available for immediate exchange.

Table 5: Correlation between potassium fractions, major nutrient uptake and post-harvest soil properties in rice.

	pH	EC	N	P	K	WSK	AK	EK	NK	LK	TK
pH	1	-0.564 ^{NS}	-0.737 ^{**}	-0.707 [*]	-0.732 ^{**}	-0.652 [*]	-0.676 [*]	-0.682 [*]	-0.719 ^{**}	-0.724 ^{**}	-0.720 ^{**}
EC	-0.564 ^{NS}	1	0.831 ^{**}	0.847 ^{**}	0.852 ^{**}	0.959 ^{**}	0.961 ^{**}	0.975 ^{**}	0.961 ^{**}	0.959 ^{**}	0.966 ^{**}
N	-0.737 ^{**}	0.831 ^{**}	1	0.997 ^{**}	0.995 ^{**}	0.829 ^{**}	0.835 ^{**}	0.852 ^{**}	0.884 ^{**}	0.916 ^{**}	0.907 ^{**}
P	-0.707 [*]	0.847 ^{**}	0.997 ^{**}	1	0.997 ^{**}	0.843 ^{**}	0.848 ^{**}	0.861 ^{**}	0.893 ^{**}	0.920 ^{**}	0.912 ^{**}
K	-0.732 ^{**}	0.852 ^{**}	0.995 ^{**}	0.997 ^{**}	1	0.851 ^{**}	0.856 ^{**}	0.869 ^{**}	0.901 ^{**}	0.929 ^{**}	0.921 ^{**}
WSK	-0.652 [*]	0.959 ^{**}	0.829 ^{**}	0.843 ^{**}	0.851 ^{**}	1	0.995 ^{**}	0.988 ^{**}	0.985 ^{**}	0.963 ^{**}	0.973 ^{**}
AK	-0.676 [*]	0.961 ^{**}	0.835 ^{**}	0.848 ^{**}	0.856 ^{**}	0.995 ^{**}	1	0.990 ^{**}	0.986 ^{**}	0.966 ^{**}	0.976 ^{**}
EK	-0.682 [*]	0.975 ^{**}	0.852 ^{**}	0.861 ^{**}	0.869 ^{**}	0.988 ^{**}	0.990 ^{**}	1	0.985 ^{**}	0.972 ^{**}	0.982 ^{**}
NK	-0.719 ^{**}	0.961 ^{**}	0.884 ^{**}	0.893 ^{**}	0.901 ^{**}	0.985 ^{**}	0.986 ^{**}	0.985 ^{**}	1	0.978 ^{**}	0.984 ^{**}
LK	-0.724 ^{**}	0.959 ^{**}	0.916 ^{**}	0.920 ^{**}	0.929 ^{**}	0.963 ^{**}	0.966 ^{**}	0.972 ^{**}	0.978 ^{**}	1	0.999 ^{**}
TK	-0.720 ^{**}	0.966 ^{**}	0.907 ^{**}	0.912 ^{**}	0.921 ^{**}	0.973 ^{**}	0.976 ^{**}	0.982 ^{**}	0.984 ^{**}	0.999 ^{**}	1

Correlation between potassium fractions, major nutrient uptake, and post-harvest soil properties in rice.

The Pearson Correlation Matrix analysis (Table 5) provides valuable insights into the relationships between soil chemical properties and potassium fractions in sodic soils. Soil pH exhibits negative correlations with various potassium fractions and nutrient uptake (ranging from -0.564 to -0.724) consistent with the findings of Dhakad *et al.*, (2017). In sodic conditions, high pH tends to reduce potassium availability as it becomes strongly adsorbed onto soil minerals and is less likely to be exchanged by other cations. This effect is exacerbated in sodic soils, where high sodium concentrations lead to increased sodium saturation on exchange sites, further hindering the release of potassium into available forms. Regarding electrical conductivity, Elbaalawy *et al.*, (2016) reported a strong positive correlation with all potassium fractions and nutrient uptake (ranging from 0.959 to 0.975). Higher salinity improves ion exchange capacity, facilitating the release of potassium from various soil fractions into the soil solution, making it more accessible for plant roots and enhancing uptake.

In addition to pH and EC, the uptake of macronutrients nitrogen, phosphorus, and potassium shows strong positive correlations with each other and with potassium fractions. The correlation values between nitrogen and phosphorus (0.997), nitrogen and potassium (0.995), and nitrogen and the other potassium fractions (ranging from 0.829 to 0.916) highlight a strong interrelationship between these nutrients in sodic soils. These results, in line with Laalithya *et al.*, (2022), suggest that the uptake of these macronutrients is closely linked, likely facilitating the overall nutrient uptake by plants. The high positive correlations between nitrogen, phosphorus, and potassium emphasize a synergistic effect, where the uptake of one nutrient enhances the availability

and uptake of others, contributing to improved nutrient dynamics and a more balanced soil fertility status.

The relationships between various potassium fractions in the soil, including water-soluble K, available K, exchangeable K, non-exchangeable K, lattice K and total K, highlight a complex and interconnected system. As Laxminarayana (2009) explains, all potassium fractions exhibit highly significant positive correlations, with values ranging from 0.829 to 0.999, indicating a dynamic equilibrium between these forms. The strongest correlations are found between lattice K and total K, suggesting that potassium stored in the lattice form plays a central role in the overall potassium pool. Furthermore, the significant positive correlations between water-soluble and exchangeable K fractions with other potassium forms suggest that these are key contributors to potassium availability. Even non-exchangeable or fixed K fractions show positive relationships, likely due to the gradual release of fixed K into the soil solution when exchangeable potassium levels are depleted, helping to restore balance, as noted by Sekhon *et al.*, (1992). Additionally, the positive correlations between potassium fractions, nutrient uptake and soil properties such as electrical conductivity further emphasize that changes in one fraction may influence others, reinforcing the importance of maintaining a balanced nutrient profile for efficient potassium availability in sodic soils.

Conclusion

The present study showed that a three-split potassium application, at basal, 30 DAT, and 60 DAT, outperformed a two-split approach in maintaining potassium availability and preventing its conversion to non-exchangeable forms. This method effectively supports continuous plant growth, leading to significant improvements in growth, yield and nutrient uptake of paddy under sodic soil. Overall, the findings emphasize the importance of strategic potassium management for optimizing crop performance and

maximizing yield. Furthermore, the enhanced distribution of potassium fractions fosters better nutrient availability, contributing to more efficient nutrient utilization and healthier crop.

References

- Annapurna, M.V., Kadam B.S. and Surabhi H.K. (2017). Distribution of different forms of potassium of representative soil series of sub-montane zone of Maharashtra, India. *Int. J. Curr. Microbiol. Appl. Sci.*, **6(7)**, 2648-2653.
- Chaudhari, A.V., Mane S.S. and Chadar B.R. (2018). Effect of graded levels of potassium on growth, yield and quality of black gram. *Int. J. Curr. Microbiol. Appl. Sci.*, **6**, 1607-1612.
- Das, K., Singh S.K. and Shyampura R.L. (1993). Forms of potassium in relation to land form and soil properties of Basaltic Terrain. *J. Indian Soc. Soil Sci.*, **41(2)**, 557-559.
- Dhakad, H., Yadav S.S., Jamra S., Arya V., Sharma K. and Gaur D. (2017). Status and distribution of different forms of potassium in soils of Gwalior District (MP). *Int. J. Chem. Stud.*, **5(5)**, 161-164.
- Dhawan, S., Pareek B.L. and Mathur C.M. (1968). Studies on the forms of potassium in soils of Rajasthan. *J. Indian Soc. Soil Sci.*, **16**, 55-60.
- Elbaalawy, A.M., Benbi D.K. and Benipal D.S. (2016). Potassium forms in relation to clay mineralogy and other soil properties in different agro-ecological sub-regions of northern India. *Agric. Res. J.*, **53(2)**.
- Garg, B.K. and Gupta I.C. (1997). Saline wastelands environment and plant growth, 287.
- Gnanasundari, R., Sellamuthu K.M. and Malathi P. (2020). Distribution and variation of potassium in black soil at different stages of crop growth in maize (*Zea mays*). *Asian J. Phys. Chem. Sci.*, **8(4)**, 14-21.
- Hou, W., Xue X., Li X., Khan M.R., Yan J., Ren T. and Lu J. (2019). Interactive effects of nitrogen and potassium on: grain yield, nitrogen uptake and nitrogen use efficiency of rice in low potassium fertility soil in China. *Field Crops Res.*, **236**, 14-23.
- Jackson, M.L. (1973). *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi. 134-204.
- Laalithya, M.S., K. Narayan Rao, H. Veeresh, Rajesh N.L. and Beladhadi R.V. (2022). Forms and Distribution of Potassium Fractions in different Production Systems of Kalyana Karnataka Region. *Biol. Forum – Int. J.*, **14(4)**, 675-683.
- Laxminarayana, K. (2009). Estimation of soil potassium availability for predicting the response to applied potassium in rice field. *ORYZA-Int. J. Rice*, **46(2)**, 124-133.
- Lim, C.H. and Jackson M.L. (1982). Dissolution for total elemental analysis In: Methods of soil analysis Part II. *Chemical and Microbiological properties*. **9(1982)**, 1-12.
- Liu, S.T. and Yao Y.X. (2003). Effects of long-term fertilization on dynamics of phosphorus and potassium in soil. *Ecol. Environ.*, **4**: 452-455.
- Mehdi, S.M., Hassan G, Sarfraz M., Sadiq M., Hassan N.M. and Shabbir G. (2001). Potassium deficiency and response of rice to its application in Hafizabad district. *J. Biol. Sci.*, **1(12)**, 1112-1115.
- Nand, M.M., Singh S.P., Kumar A. and Alam M.M. (2019). Potassium fractions affected by split application of potassium in rice (*Oryza spp.*) in calcareous soil of North Bihar. *IJCSS*, **7(2)**, 964-966.
- Patil, S., Basavaraja P.K., Parama V.R.R., Chikkaramappa and Sheshadri T. (2017). Effect of Different Sources and Levels of K on Maize (*Zea mays* L.) Yield, Nutrient Content and Uptake by Maize Crop in Low K Soils of Eastern Dry Zone of Karnataka, India. *Int. J. Curr. Microbiol. Appl. Sci.*, **6(8)**, 577-587.
- Pettigrew, W.T. (2008). Potassium influences on yield and quality production for maize, wheat, soybean and cotton. *Physiol. Plant*. **133**, 670-681.
- Ravichandran, M. and Sriramachandrasekharan M.V. (2011). Optimizing timing of potassium application in productivity enhancement of crops. *Karnataka J. Agri. Sci.*, **24**, 75-80.
- Safaa, R., EL-Lethy, Magdi T., Abdel H. and Fatma R. (2013). Effect of potassium application on wheat (*Triticum aestivum* L.) cultivars grown under salinity stress. *World Appl. Sci. J.*, **26(7)**, 840-850.
- Sehkon, G.S., Brar M.S. and Subba Rao A. (1992). Potassium in some benchmark soils of India. PRII Special Publication, Potash Research Institute of India, Gurgaon, Haryana.
- Sharma, R.P. and Verma T.S. (2000). Effect of long term lantana addition on soil potassium fractions, yield and potassium uptake in rice wheat cropping in acid Alfisols. *J. Potassium Res.*, **16**, 41- 47.
- Thippeswamy, H.M. (1995). Dynamics of potassium and crop response studies in selected soil series of Alfisols of Karnataka. *Ph.D. (Agri.) Thesis*, Univ. Agric. Sci. Bangalore.
- Zorb, C., Senbayram M. and Peiter E. (2014). Potassium in agriculture status and perspectives. *J. Plant Physiol.* **171**, 656-669.